Transport of Objects in a Robotic Storage Facility

The final project task is to simulate an autonomous robot tasked with transporting various objects around a storage facility. Figure 1 shows a schematic layout of the storage facility's Robot Operating Floor. This resembles what you would see if looking down from above.

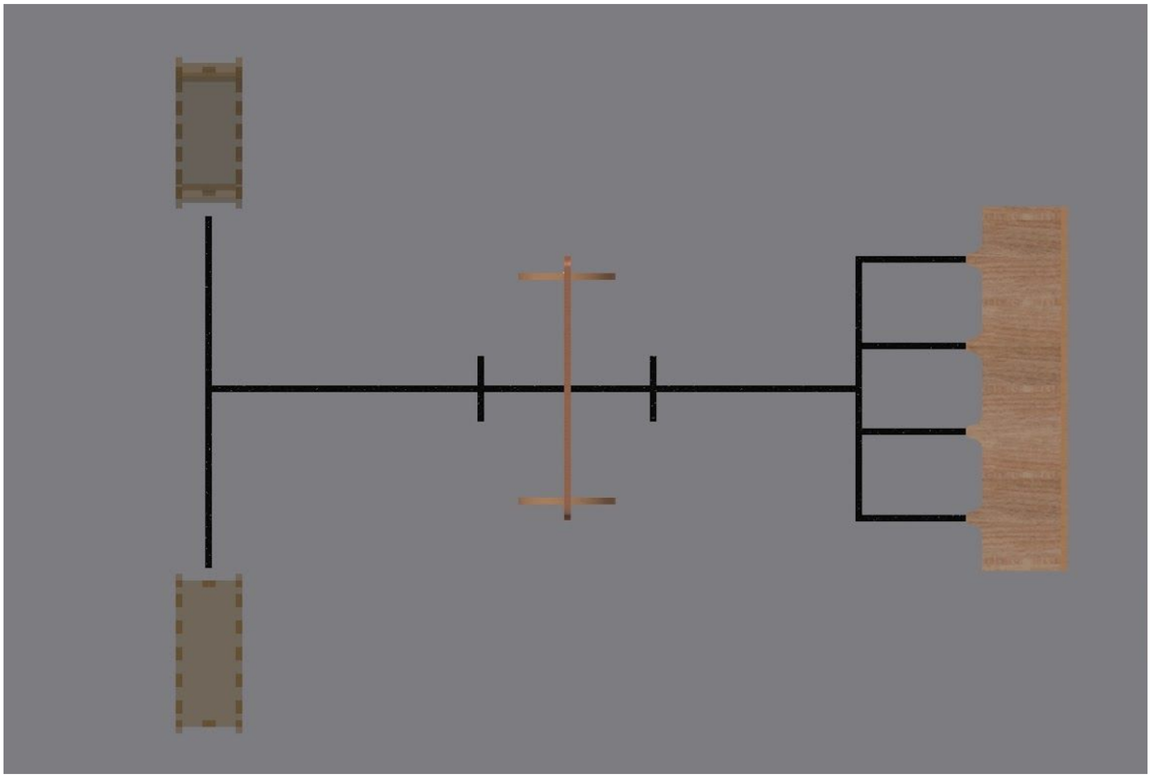


Figure 1: Robot Operating Floor

There are four sections of the Robot Operating Floor: Long Term Storage, Pick Up, Drop Off, and the Gate. The Drop Off location is a long smooth trough that is four (4) inches wide and ten (10) inches long with one (1) inch high walls surrounding it. The Pick Up location is a long trough tilted at 30 degrees, four (4) inches wide, and ten (10) inches long with one (1) inch high walls surrounding it. The Long Term Storage location is a four wide by three tall set of Storage Slots that is used for long term storage of materials not currently requested by the storage system. The Pick Up location will start with either one or two objects that must be brought to Long Term Storage. The Drop Off location will start with nothing but will contain object(s) as a result of a successful robot simulation. These three locations have no form of visible signal for when any of their Storage Slots are filled. Storage Slots are six inch cubes (when measured from the interior). The Storage Slots for Long Term Storage each have one side removed, exposing the inside to the Robot Operating Floor, this allows for robots to place and retrieve objects from Long Term Storage. The Gate is a structure with a 14in wide and 10in tall opening centered on the line connecting Long Term Storage to the Drop Off and Pick Up locations. There is a marker preceding the Gate on either side by six (6) inches as a warning to any approaching robots on the Robot Operating Floor. Any part of a robot that moves in relation to the field must fit through this gate. Any part of a robot that does not move in relation to the field will be considered a Field Augmentation. Field Augmentations must not damage the field and must be able to be set up and taken down easily, requiring no more than five (5) minutes for each process.

Briefly, the robot needs to:

- Navigate to the Pick Up location,
- Remove an object from the Pick Up location,
- Signal that they have possession of the object,
- Navigate to Long Term Storage,
- Store the object in the designated empty Long Term Storage Storage Slot,
- Signal that the object is now in Long Term Storage,
- Remove the requested object from its corresponding Long Term Storage Slot,
- Signal that they have possession of the object,
- Navigate to the Drop Off location,
- Place the requested object in the Drop Off location,
- Signal that the object has been placed in the Drop Off location.

Task Details:

- The operator can drive (tele-operate) the robot up to a Storage Slot. This tele-operated driving is taking place via a high-bandwidth, real-time video connection from a camera onboard the robot.[1] A V-shaped notch on the front of the robot is allowed to gently push against the alignment guides in front of each column of Storage Slots in Long Term Storage. The objects used for this simulation will be no larger than a three inch cube, but will be larger than a two inch cube. See Appendix A for details.
- The robot needs to autonomously remove the object from the Pick Up location. The robot will need to use a vertical pull of a few inches in order to have the object clear the walls bordering the Pick Up location. *Points will be deducted if the object substantially rubs against the walls of the Pick Up location during object removal* (such rubbing may damage the object and increases the cost to remanufacture/dispose it).[2]
- When the object has been removed from the Pick Up location, tele-operation is no longer possible. This is due to the object blocking the view of the camera, such that the notional remote video operation of the robot is no longer possible. Field communications are still possible though – see below. The robot now needs to autonomously navigate its way to the designated Long Term Storage location.
- The Storage Control System (i.e., the playing field control computer) will communicate to the robot as to which Storage Slot the object is to be stored in.[3]
- The robot needs to lift the object to the correct height and align it with the empty Storage Slot; the object can then be inserted into the Storage Slot. Physical alignment devices will be available on the playing field to aid the robot in getting properly lined up with the Storage Slots.

[1] The camera and video link is notional. We do not have sufficient resources for each team to have such a camera. Robot drivers will instead use their Mark II eyeballs to simulate the camera while tele-operating the robot.

[2] We will supply servos to each team in the kit of parts. The team may design and use a gripper using this provided servo if they wish.

[3] Just to make it more interesting, other message types will also be broadcast. Robots should additionally be aware that messages may be directed to other robots working in the area, so they need to pay attention only to messages addressed to themselves as well as those broadcast to all robots. See the message packet protocol for more details on robot addressing.

- Having stored the object, the robot may once again be tele-operated to pick up a requested object from Long Term Storage. Optionally (and for additional credit), the robot can autonomously navigate to the requested objects location. As before, the object will block the camera once the object has been removed. The robot must therefore autonomously navigate its way to the Drop Off location.
- While the robot is in possession of an object, the robot must continuously display a visual alert (at least a flashing red LED). It should also broadcast 'Object Possession' messages over the field communications channel for additional credit.
- If using field communications in any way, a robot must respond as appropriate to all messages. These could be messages broadcast to all robots, or it could be a message sent to a specific robot. The 'address' for each robot is your assigned team number. See the message protocol for details. Successful responses to field communication messages (when appropriate) will result in a point bonus.
- An actuation mechanism is required to be incorporated into the robot in some way. It should be used in a way that is meaningful and important to the operation of the robot. This actuation method must be approved by course staff before implementation in order to count towards this requirement.

Scoring:

There will be an overall time limit of 10 minutes for the game. The goal is to score as many points as you can during that time. Points are awarded or deducted as detailed in Appendix B: Scoring Rubric.

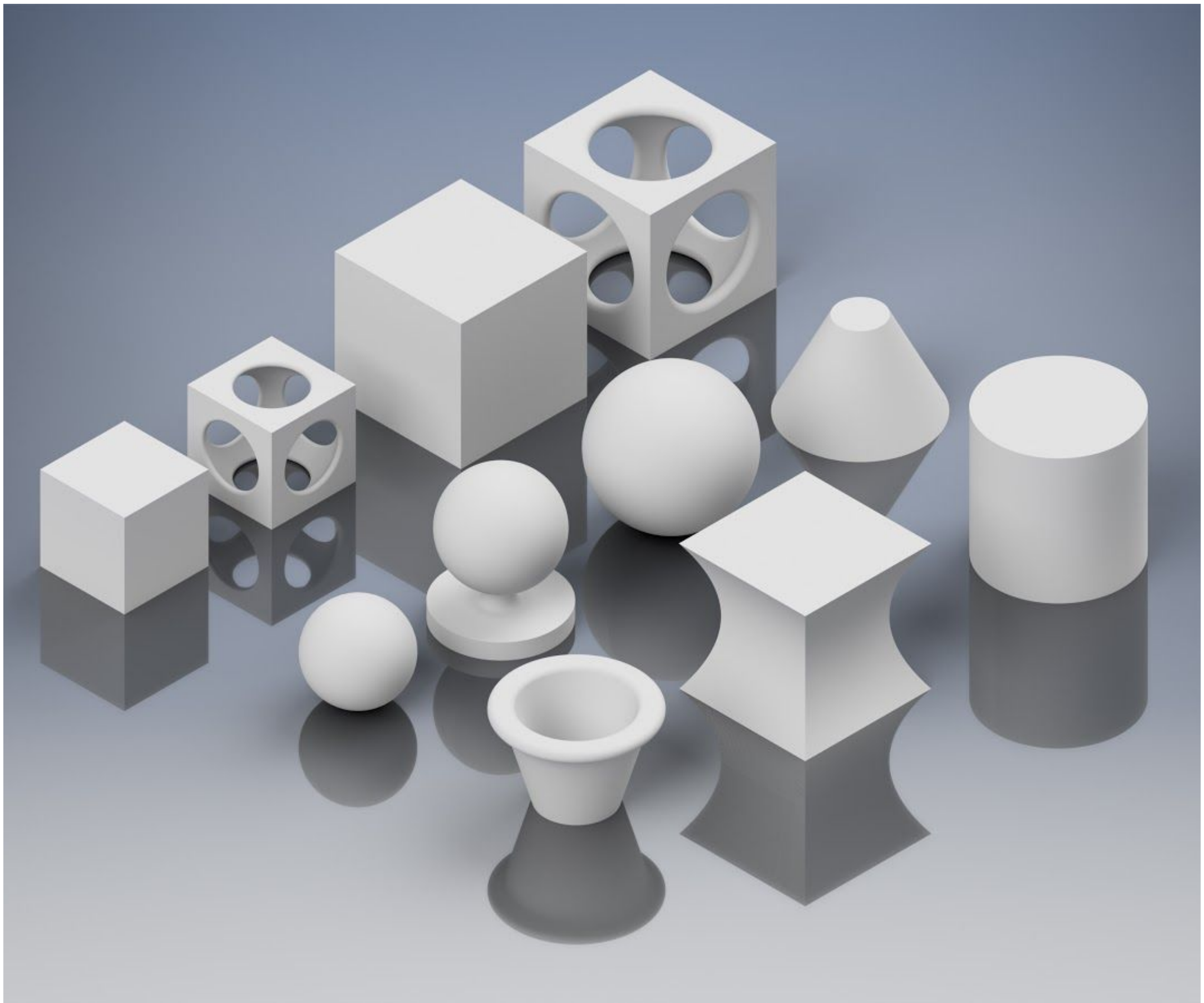
Project Goals:

- Require use of most of the material taught in RBE 2001 as well as material previously learned in RBE 1001.
- Demonstrate good software development and coding practices.
- Deal with a mix of autonomous and tele-operation in the robot tasks.
- Use field communications for autonomous interaction with the Storage Control System (e.g., the playing field control computer). A simple message-packet protocol has been defined to accomplish this. See the separate Field Communication Protocol document for details.
- Demonstrate understanding of and an ability to use a simple message packet protocol (regular structure, addressing, checksums, etc.).
- [Optional] Use field communications for debugging of untethered operation.
- Provide an opportunity for and encourage the use of:
    - an actuation mechanism for a useful function
    - other mechanisms as appropriate

  to attain the different required orientations of the objects (vertical and horizontal).
- Demonstrate, encourage and require good technical communications in the form of:
    - Supplied project documents
    - Informal preliminary design review
    - More formal critical design review
    - Final formal project presentation
    - Final formal project report
    - Demo of the robot in action

Appendix A: Object Types

- 2in cube
- 3in diameter
- 2in tall cylinder
- 3in cube
- 3in sphere
- cone shape
- small plant pots
- other objects at the course staffs discretion



Appendix B: Scoring Rubric

Category	Description	Score Range	Perfect Score	Weight	Totals
Overall Design	How well does the overall design work towards accomplishing the project goals? (Overall design is clearly intended for the project (4) / Overall design lends itself to final project but some aspects seem misguided (3) / Overall design is misguided but still works for the project (2) / Some aspects of overall design work towards project goals but most of the design is extraneous (1) / Overall design appears to be for a different project entirely (0))	0 - 4	4	5	20
Innovation/Creativity	How much innovation and/or creativity is evident in the design? This could include hardware as well as the control algorithms, e.g. software. (Very creative and innovative (3) / no innovation or creativity apparent (0))	0 - 3	3	5	15
Reliability - mechanical	Rate the reliability of the mechanical aspects of the robot. (Solid design execution and functions properly (3) / occasionally needs repair or reset to function (2) / constantly in need of repair or reset to function (1) / no functionality (0))	0 - 3	3	5	15
Reliability - control program	Rate the reliability of the control (software) aspects of the robot. This is from the observed behaviors. The code itself (design / structure / commenting) will be separately reviewed as part of the final report. Score: 0 = poor → 3 = excellent	0 - 3	3	5	15
Mech - Actuation requirement	The robot is required to have an approved actuation mechanism. (not present (0) / present (1))	0 - 1	1	15	15
Mech - Actuation Mechanism use	How central to the operation of the robot is the actuation mechanism? (not present (0) / present but not central (1) /very central (2))	0 - 2	2	5	10
Mech - Dynamics	How well were forces/torques accounted for? Does the design indicate an awareness of and attempt to deal with forces, moment arms, etc.? (not accounted for (0) / attempt was clearly made (1) / all forces/torques are accounted for (2))	0 - 2	2	5	10
Mech - End Effector Design & Operation	Is the end effector design suitable for the task? How well does the end effector work? Does the end effector design detract from its operation? (end effector inhibits robot functionality (0) / end effector is present but does not affect robot functionality at all (1) / end effector works well but not for all objects (2)/ end effector works flawlessly (3))	0 - 3	3	5	15

Electrical - neatness	Has there been an attempt to tidy up the wiring and keep it neat? Labeling wires should add to this score (but not detract if not present). (no attempt(0) / some neatness (1) / no room for meaningful improvement (2))	0 - 2	2	5	10
Pick Up Removal	How well was the object removed from the Pick Up location? not attempted (0) / object removal is attempted, but not successful (1) / large amounts of jostling (2) / minor bumping (3) / flawlessly (4)	0 - 4	4	5	20
Drop Off Placement	How well was the object placed in the Drop Off location? not at all (0) / object placement is attempted but not successful (1) / large amounts of jostling (2) / minor bumping (3) / flawlessly (4)	0 - 4	4	5	20
Object holding	Was an object dropped during the demo? (Yes (1) / NO (0))	0 - 1	0	-20	0
Specified Long Term Storage Storage Slot	Object was placed in the specified Storage Slot in Long Term Storage (Success (2) / wrong Storage Slot (1) / failure (0))	0 - 2	2	15	30
Stowing ability	Object is completely contained by Storage slot that it has been placed in (success or failure)	0 - 1	1	20	20
Navigation from Pick Up to Long Term Storage	Was the robot able to successfully navigate autonomously to Long Term Storage from Pick Up? (Success (1) or failure (0))	0 - 1	1	20	20
Navigation from Long Term Storage to Drop Off	Was the robot able to successfully navigate autonomously to Drop Off from Long Term Storage? (Success (1) or failure (0))	0 - 1	1	20	20
Response to "All Robot" messages	Does the robot respond appropriately to messages directed at all robots? (Success (1) / Failure (0))	0 - 1	1	5	5
Response to "Robot Specific" Messages	Does the Robot respond appropriately to messages directed to specific robots? (Success (1) / Failure (0))	0 - 1	1	5	5
Object Possession Alerts	Does the robot transmit messages stating that it has an object in its possession when appropriate? (Success (1) / Failure (0))	0 - 1	1	5	5
Heartbeat Messages	Does the robot transmit heartbeat messages when appropriate? (Success (1) / Failure (0))	0 - 1	1	5	5
Time used by team	Should be less than 10 minutes. -1 score for every minute over		0	-5	

GATE	Does the robot fit through the Gate? This does not count for field augmentations. (Yes(0)/ No (1))		0	-27.5	
	Final maximum score with field communications:				275
	Final maximum score without field communications:				235
	NOTE: Project graded out of 250 points				